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ABSTRACT

Studies were conducted to identify critical barriers which could impede the progress of Hispanic undergraduates enrolled in science and engineering programs. The underlying theme in most studies was the interplay of language in various problem-solving tasks. Studies examined: (1) predictors of academic achievement (as measured by grade point average); (2) ability of students to translate word problems into appropriate mathematical equations, with an emphasis on identifying errors caused by misinterpretations of the problem statement as opposed to errors caused by mathematical deficiencies; (3) extent to which students' academic, motivational, and socioeconomic characteristics mediated their performance in various cognitive measures; and (4) the ability of students to solve logical reasoning problems containing multiple negations. Findings indicate that Hispanic students are underprepared in comparison to Anglo students. Areas in which Hispanics displayed underpreparation are algebraic skills, language skills, and problem-solving skills requiring substantial amounts of linguistic processing. Differences in socioeconomic status between Hispanics and Anglos were also found. In addition, findings indicate that various errors committed by the Hispanics in solving mathematics and logics problems are the result of semantic difficulties and not necessarily the result of difficulties in the content area. (JN)

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BILINGUAL RESEARCH PROJECT

Identifying Learning Handicaps of College Age Spanish-Speaking Bilingual Students Majoring in Technical Subjects

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September 1, 1983

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Identifying Learning Handicaps of College Age Spanish-Speaking Bilingual Students Majoring in Technical Subjects

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This is the final report for National Institute of Education grant #NIE-G-79-0094 to the University of Massachusetts at Amherst under principal investigators William J. Gerace and Jose P. Mestre. The contents herein do not necessarily reflect the views, policy, or endorsement of the National Institute of Education.

The research conducted under this grant was aimed at identifying critical barriers which could impede the progress of Hispanic undergraduates enrolled in science and engineering programs. More specifically, the underlying theme in the majority of the studies we conducted was the interplay of language in various problem-solving tasks. These studies can be categorized into four general areas:

1. Predictors of academic achievement in mathematics for Hispanic students enrolled in technical fields. This research entailed the design and evaluation of several testing instruments for predicting academic achievement (as measured by grade point average) of Hispanic science and engineering majors. The testing instruments covered mathematics (both algebra and word problems). The results of this investigation have been published in Educational and Psychological Measurement.

2. Translation skills from natural language to the language of mathematics (equations). This research investigated the ability of students to translate word problems into the appropriate mathematical equations, with an emphasis on identifying errors caused by misinterpretations of the problem statement, as opposed to errors caused by mathematical deficiencies. Our findings were published in the Journal of Research in Science Teaching, and in a chapter for a book entitled Latino College Students.

3. Background characteristics of Hispanics enrolled in technical programs. This series of studies investigated to what extent the students' academic, motivational and socioeconomic characteristics mediated their performance in various cognitive measures. The results of these investigations were published in two articles in Integrated Education, and in one article in Vocational Guidance Quarterly.

4. Logical reasoning of Hispanic college students. This study investigated the ability of students to solve logical reasoning problems containing multiple negations. Our interest in this topic was derived from the unparallel structure between English and Spanish in the meaning of double negations. In Spanish, it is possible to write doubly-negated statements (e.g., yo no quiero nada) whose meaning is an overall negation--a situation which is not possible in grammatically correct English. Our pilot study in this area opened several interesting avenues for future investigations focusing on the role of double negations in logical reasoning and mathematical problem-solving. We hope to be able to pursue some of these research topics in the near future. The findings on this work appear in the Latino College Students book chapter.

In every one of our studies, we included a control group of non-minority students in order to perform various between-group comparisons. Interestingly, the results of our investigations revealed that Hispanic students were not unique in commiting "semantic errors" caused by misinterpreting the problem statement; many of the semantic errors we uncovered in the Hispanic group were also committed by the control group of non-minority students. Judging from how well our presentations at professional meetings have been received, we are hoping that there will be an increasing interest in a research area we have termed "linguisthematics"--the study of the language of mathematics, particularly as it pertains to people's understanding of this language, and to the interplay of this language with the problem-solving process.

Our accomplishments during the 4-year grant period have been substantial. We presented 8 papers at professional meetings, published 5 articles in refereed journals, were invited to write a contributed chapter to a book, Latino College Students, to be published by Teachers College

Press/Columbia University (M. Olivas, Ed.), and have one article being reviewed for a chapter in another edited book.

In the next two pages, we will summarize the conference papers presented and the articles published during the grant period. We have included our 6 published articles as Appendices A through F. These articles detail the research conducted during the grant period

Conference Presentations

Mestre, J. Some factors affecting the technical education of college age Hispanics. Presented at Ninth Annual International Bilingual Education Conference, National Association for Bilingual Education, April, 1980, Anaheim, California. (ERIC ED 186 284)

Gerace, W. and Mestre, J. The interdependence of mathematical skills, grade-point average and language proficiency for Hispanic college students. Presented at Remedial and Developmental Mathematics in College: Issues and Innovations, City University of New York, N.Y., April 9-11, 1981. (ERIC ED 204 150)

Gerace, W. and Mestre, J. Problem-solving skills of Hispanic college students. Presented at Remedial and Developmental Mathematics in College: Issues and Innovations, City University of New York, N.Y., April 9-11, 1981. (ERIC ED 204 151)

Robinson, H., Gerace, W. and Mestre, J. Factors influencing the performance of Hispanic students in math and science-related areas. Presented at Remedial and Developmental Mathematics in College: Issues and Innovations, City University of New York, N.Y., April 9-11, 1981. (ERIC ED 204 149)

Burns, M., Gerace, W., Mestre, J. and Robinson, H. The current status of college Hispanic technical students: How can we improve recruitment and retention. Presented at Tenth Annual International Bilingual Education Conference, National Association for Bilingual Education, May 23-30, 1981, Boston, MA. (This article was also published in Integrated Education and is enclosed later in this report)

Mestre, J. Just how important are language skills in mathematical problem-solving. In S. Wagner (Ed.), Proceedings of the Fourth Annual Meeting of the North American Chapter of the Psychology of Mathematics Education, Department of Mathematics Education, University of Georgia, Athens, GA, October 23-25, 1982, pages 126-132.

Invited Conferences

Mestre, J. The Latino science and engineering student: Some recent research findings. Presented at Latino College Students Conference, Educational Testing Service, Princeton, N.J., January 28-29, 1983. (See also book chapter by this same title included later in this report)

Mestre, J. "I'm sorry, but you solved the wrong problem": The role of semantics in problem-solving. Presented at Mathematics Achievement Among Language Minority Students. Sponsored by the National Institute of Education, Washington, D.C., March 10-11, 1983.

Manuscripts Being Considered for Publication

Gerace, W. and Mestre, J. Technical education today: The need for a greater emphasis of verbal skills and their relation to successful problem-solving. Submitted to H. Trueba (Ed.) for a book volume being considered by Ablex Publishing Co., Norwood, N.J.

Following is a list of articles published during the grant period. These articles are also included in the appendices that follow and constitute the main body of this final report.

Journal Articles

Mestre, J.P. Predicting academic achievement among bilingual Hispanic college technical students. Educational and Psychological Measurement, 1981, 41, 1255-1264.

Robinson, H., Gerace, W.J. and Mestre, J.P. Factors influencing the performance of Hispanic students in math and science-related areas. Integrated Education, 1981, 18, 38-42.

Mestre, J.P., Lochhead, J. and Gerace, W.J. The interdependence of language and translational math skills among bilingual Hispanic engineering students. Journal of Research in Science Teaching, 1982, 19, 399-410.

Mestre, J.P. and Robinson, H. Academic, socioeconomic, and motivational characteristics of Hispanic college students enrolled in technical programs. Vocational Guidance Quarterly, 1983, 31, 187-194.

Burns, M., Gerace, W.J., Mestre, J.P. and Robinson, H. The current status of college Hispanic technical students: How can we improve recruitment and retention. Integrated Education, 1983, 20, No. 1,2 in press.

Book Chapter

Mestre, J.P. The Latino science and engineering student: Some recent research findings. Latino College Students, M. Olivas (Ed.). Scheduled for release in 1983 by Teachers College Press, Columbia University, N.Y.

The Latino Science and Egineering Student: Some Recent Research Findings *

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The representation of Hispanics in professional technical fields is disproportionately low in comparison to the Hispanic representation in the mainland United States. The extent of this underrepresentation is detailed in a publication by the National Center for Education Statistics entitled The Condition of Education for Hispanic Americans (Brown, Rosen, Hill and Olivas, 1980). For example, the enrollment statistics for 1978 show that, out of all Hispanics attending college in the mainland, the percentages enrolled in engineering and the physical sciences were 2.4% and 0.8%, respectively; in comparison, the percentages of whites enrolled in engineering and the physical sciences (out of the total white underrgraduate enrollment) were 5.2% and 1.5%, respectively. The situation is even worse at the postgraduate level--the corresponding percentages of postgraduate enrollments for Hispanics in the mainland in engineering and the physical sciences are 1.5% and 1.4%, compared to 4.2% and 3.1% for whites.

The causes of this underrepresentation are many and varied. In terms of undergraduate enrollments, only 2.8% out of all undergraduates attending 4-year programs in 1978 were Hispanic, despite the fact that Hispanics comprised 5.6% of the mainland population. High school dropout rates also contribute to the problem, as Hispanics between the ages of 14 and 19 are twice as likely not to have completed high school as non-minority students in the same age group. Socioeconomic status (SES) measures indicate large disparities between Hispanics and whites. Given the fact that SES has been shown to correlate with educational aspirations and academic preparedness (Sewell, 1971; Sewell and Hauser, 1975), Hispanics have a decided disadvantage (Ramirez and Castañeda, 1974; Vasquez, 1982). Furthermore, recent disclosures by the Educational Testing Service have revealed that Hispanics are underprepared in mathematical and verbal skills as measured by performance on the Scholastic Aptitude Test ("Board Says...", 1982). However, some

researchers have recently expressed concern about the validity of the SAT for use with Hispanic students (Duran, this volume; Mestre, 1981).

Unfortunately, few educational research studies have focused on the specific problems endemic to Hispanics. Studies which explore the reasons for low involvement of Hispanics in the math and sciences are few. It is therefore difficult to design intervention programs for improving the Hispanic underrepresentation in the technical fields without the appropriate research base to be able to define some of the crucial problems. Perhaps the research situation is best described in a recent evaluation by the Latino Institute of Chicago which revealed that only one percent of the monies awarded by the larger grant foundations directly benefited Hispanics (Facundo, 1981).

The purpose of this chapter is to report on a series of research studies conducted with Hispanic college students enrolled in science and engineering programs. Although Hispanic college students have not been "popular" for use as research subjects, there is much to be learned by studying this particular group. First, what we learn about the difficulties that these students experience during various problem solving tasks should provide data useful in designing effective intervention programs at the pre-college level. In addition, we can study how and to what extent language deficiencies interfere in the problem solving process. Lastly, such studies will help illuminate the role of language, and especially of bilingualism, in the development of cognitive skills.

With few exceptions, the underlying theme in all of the studies discussed here is the interplay of language in problem solving. Educators in the sciences agree that one of the most difficult steps in the problem solving process is the translation of the problem statement into the appropriate symbolic or mathematical notation. Not only does the ability to correctly solve a problem hinge on accurately translating the problem, but it is

precisely in this step that most errors occur--errors which are often the result of inappropriate interpretations of textual information contained in the problem statement.

Before proceeding, we will offer a word of caution. As indicated above, the role of SES in studies investigating the cognitive performance of minority populations is important. That SES is an important factor in the studies reported here is not at issue; however, the extent to which SES mediates performance in the mathematics and language proficiency measures used is not clear. It is therefore important to keep in mind the possible confounding role of SES on the results reported in this chapter.

Review of the Literature

As has already been mentioned, the number of studies that have investigated problem solving with bilingual populations is few. The oldest and perhaps best known study using Puerto Rican bilingual subjects was conducted by the International Institute of Teachers College of Columbia University (1926). This study found that the English mathematical problem solving ability of twelfth grade Puerto Rican bilinguals educated in Puerto Rico was significantly below that of U.S. twelfth graders, despite the fact that the Puerto Rican students had been receiving mathematics instruction in English since the fifth grade. Similar findings were reported by Macnamara (1967) who reviewed numerous studies of arithmetic reasoning among bilinguals. Macnamara concluded that bilinguals appear to have more difficulties than monolinguals in solving mathematics problems which require semantic processing, even when the language of the problems was also the language used for instruction. There did not appear to be any differences, however, between bilinguals and monolinguals in problem solving performance on arithmetic problems requiring no semantic processing.

Similar findings were obtained by Kellaghan and Macnamara (1968) in a study of the problem solving skills of Irish fifth standard primary students. They found a weaker performance in problems requiring substantial amounts of semantic processing, if the problems were given in the students' weaker language. Not only were the problems equated for number of words across the Irish-English versions, but students had displayed an understanding of each separate component of the problems' statements in their weaker language. Another finding from this study was that problem reading time was longer in the weaker language by factors ranging from 1.4 to 1.7, a finding consistent with other studies (Lambert, Havelka, and Gardner, 1959; Kolers, 1966). These results suggest that the linguistic processes mediating the decoding process necessary for understanding a problem at a sufficiently high level to be able to solve it go beyond simple semantic decoding. Macnamara (1967) explained these findings by pointing out that longer decoding times in the weaker language imply greater difficulties with that task, thereby placing an added burden on a short term memory which is already limited both in the quantity of information it can store, and in the length of time for which it can store it. This additional burden on short term memory has a confounding effect on solving problems in a weaker language.

A more recent investigation by DeAvila and Duncan (1980) studied the performance of 903 children from 9 distinct ethnolinguistic groups on various academic, cognitive, and linguistic tasks. The single best predictor of academic performance found in this study was language proficiency, indicating that the difficulties encountered by the students in performing the various tasks may have been linguistic rather than intellectual in nature. In an investigation with Hispanic and Anglo ninth graders enrolled in Algebra I, Gerace and Mestre (1982) found that Hispanic and Anglo students alike had a difficult time verbalizing the procedure they used in solving word problems,

even when they could operationally obtain the solution to the problems. This ability to verbalize was poorest among those Hispanics who were language-deficient. Results from this study also revealed that problem syntax was a very important factor in determining problem solving difficulty, and that language-deficient Hispanics often did not understand word problems well enough to attempt a solution. Further, even though errors caused by misinterpreting a phrase or word in a problem were committed by all students, the Hispanic group was more prone to this type of error.

The evidence thus supports the premise that language proficiency mediates complex cognitive tasks. An explanatory hypothesis espoused by Cummins (1979) takes into account the effect of language proficiency on cognitive functioning. Cummins' "linguistic threshold hypothesis" posits that "there may be a threshold level of linguistic competence which bilingual children must attain both in order to avoid cognitive deficits, and to allow the potentially beneficial aspects of becoming bilingual to influence their cognitive growth" (1979,p. 229). The actual threshold level is not defined in absolute terms, since it depends on the individual and on the demands of the cognitive task in question. Cummins does define three types of bilingualism. The first, "semilingualism", is characterized by a lower-than-threshold level of linguistic competence in <u>both</u> languages. In semilingualism, both languages are sufficiently weak to impair the quality of interaction between the student and his/her educational environment. The negative effects of semilingualism are no longer present in "dominant bilingualism", characterized by an above-threshold level of competence in <u>one</u> language. Dominant bilingualism is supposed to have neither a negative nor a positive effect on cognitive development, although it could have a negative effect on cognitive functioning in tasks that require substantial linguistic demands on the weaker language. The last category, "additive bilingualism", is one conducive toward positive

cognitive effects. Additive bilingualism is characterized by above-threshold competence in both languages.

The Hispanic college students in the studies we are about to review appear to be semilingual in the Cummins sense. Although there is no single piece of evidence which gives incontrovertible proof to the notion that poor language skills mitigate against successful problem solving, we will present numerous findings which, collectively, lend strong support to this view. Listed at the conclusion of this chapter will be suggestions to combat some of the extant problems encountered by Hispanic students who wish to pursue technical fields.

Review of Research Studies

The studies discussed here were conducted during the 1979-1982 academic years. Although the number and ethnicity of the subjects who participated varied from study to study, the approximate breakdown of the ethnicity of the Hispanic participants was fairly consistent across studies. Half of the Hispanics were of Puerto Rican descent, while the remaining half were of South American, Central American, or Caribbean descent. Approximately one-third of the Puerto Rican group consisted of students who were living in Puerto Rico and came to the mainland for the expressed purpose of attending college, and then returned to Puerto Rico during the summer months. Another third of the Puerto Rican group, as well as most of the non-Puerto Rican Hispanics, immigrated to the mainland during their pre-college years. The remaining one-third of the Puerto Rican group were born and raised on the mainland--many of these students were dominant English speakers. Further details on the subjects used in our studies can be found in the references cited throughout this chapter.

All of our studies also included a control group of Anglo students. This

permitted us to assess how factors such as language proficiency, academic preparation, and socioeconomic status affected problem solving performance, and college performance as measured by grade point average, across the two groups.

Academic Preparation: The Overall Picture

One of the studies conducted (Mestre, 1981) was an evaluation of the students' academic preparation in verbal and mathematical skills. Several tests covering language proficiency, mathematical computation, and word problem solving proficiency were administered to the students. Given that we were also interested in identifying any possible differences in performance across language, and that there is a paucity of advanced testing instruments in parallel English-Spanish forms, we were were forced to develop several mathematical testing instruments. A brief description of these is given below:

1. Formula Translation Examination (FTE) and Traduccion de Formulas (TDF). These two tests contained 14 questions each and were designed to evaluate the students' ability to read a sentence stating a relationship between two variables and then write an equation to express that relationship. For example, a sample question from each of the FTE and TDF are given below:

FTE #1: Write an equation using the variables S and P to represent the following statement: "There are six times as many students as there are professors at this university." Use S for the number of Students and P for the number of professors.

TDF #1: Escriba una ecuación usando las cantidades I y M para representar esta declaración: "En esta universidad hay seis veces mas ingenieros que matemáticos." Use I para representar el número de ingenieros y M para el número de matemáticos.

2. Short Algebra Inventory (SAI): There were two Short Algebra Inventory

tests in English and Spanish, each containing 20 questions. The problems required a knowledge of basic algebra, and demanded very little semantic processing on the part of the student. Two problems from the English version of the SAI are:

Solve for X and Y: $2X + Y = 2$

$X - 3Y = -27$

Factor the following: $4X^2 + 10X - 6$

3. Word Problem Inventory (WPI): This instrument consisted of two equivalent English/Spanish versions of a 15 question test. Problems on both versions required substantial amounts of semantic processing. Sample problems from these two tests are shown below. The results on the two English problems will be discussed in detail in the next section:

WPI-Eng #1 In an engineering conference, 9 meeting rooms each had 28 participants and there were 7 participants standing in the halls drinking coffee. How many participants were at the conference?

WPI-Eng #2 A carpenter bought an equal number of nails and screws for $5.70. If each nail costs $.02 and each screw costs $.03, how many nails and how many screws did he buy?

WPI-Spa #2 Un muchacho compra el mismo número de lápices que de plumas por $.84. Cada Lapiz vale $.05 y cada pluma vale $.07. Cuantos lápices y cuantas plumas ha comprado?

Among the standardized measures used were the following:

4. The College Board Scholastic Aptitude Test (SAT), (Educational Testing Service, 1948-1983).

5. Test of Reading (TOR), Level 5, and Prueba de Lectura (PDL), Nivel 5 (Guidance Testing Associates, 1962): These two language instruments are intended to be equivalent versions, one in English and the other in Spanish. The three topics covered in these two tests are: Vocabulary, Speed of Comprehension, and Level of Comprehension.

6. Test of General Ability (TOGA), Level 5, Part III-Computation (Guidance Testing Associates, 1962): The TOGA-Computation is a non-verbal computation test covering addition, subtraction, multiplication, and division of both whole numbers and fractions.

The means and standard deviations on these tests for 60 Hispanic science and engineering majors, and for a corresponding group of 73 Anglo science and engineering majors, is shown in Table 1. Also shown in Table 1 is each group's college grade point average (GPA). Table 2 displays the Pearson correlation coefficients among all 10 variables.

.....Insert Table 1 about here.....

Table 1 shows that the Hispanic group was academically underprepared in comparison to the Anglo group. On the TOR and the PDL, the Hispanic group showed a balanced performance across English and Spanish; only 11 students showed a performance dissimilar enough across English and Spanish to be deemed "unbalanced." However, the Anglo group has a decided advantage in English language proficiency as measured by the TOR; the Anglo group was also better prepared in mathematical, manipulative, and computational skills as measured by the SAI and the TOGA-Computation. Given the large differences between the

Anglo and Hispanic groups in academic preparation, it is not surprising to find a statistically significant difference (05 level) in college performance between these two groups, as measured by GPA.

There is also an interesting pattern from the correlation coefficients of Table 2. First, the GPA of the Hispanic group is more strongly correlated with the three language proficiency measures of the TOR than is the GPA of the Anglo group. Not surprisingly, this pattern persists for mathematical measures requiring substantial amounts of linguistic proficiency, such as the WPI and FTE. However, it is surprising to find the strong and persistent correlations between the three TOR language measures and the mathematical tests requiring almost no linguistic proficiency, such as the TOGA-Computation and the SAI. Even though the larger variances among these measures for the Hispanic group shown on Table 1 necessarily imply larger correlation coefficients for this group, trying to correct for this effect results in the Hispanic group maintaining much stronger correlation coefficients between the TOGA-Computation/SAI tests and the three language proficiency measures of the TOR (See, for example, Hopkins and Glass, p.141, eqn. 3.1, 1978, for a way to correct for large differences in variance between samples when computing correlation coefficients.)

.....Insert Table 2 about here.....

Mathematical Decoding

The results presented in the last section provide a general picture of the academic preparedness of Hispanic students--general in that nothing is known about the specific kinds of difficulties that the students are having.

In this section, we will explore the problem solving process in more detail. In particular, the translation process from textual to symbolic representations will be explored. Only by investigating some of the errors committed by the students in the translation process will we be able to sort out those errors which stem from difficulties with language from those which stem from difficulties with mathematics.

We will begin by discussing the performance on several problems from the Formula Translation Exam. The "students and professors" problem from the FTE shown in the last section is one which has attracted much attention in recent mathematics educational research. The reason for this attention is that, even though it is a relatively simple problem, Anglo engineering students have inordinate difficulties solving it. For example, Clement, Lochhead and Monk (1981) have shown that in the "students and professors" problem, 37% out of a sample of 150 Anglo freshman engineering majors answered the problem incorrectly. A full two-thirds out of all incorrect answers consisted of students writing the answer 6S=P, where the variables appear in the reverse order from the correct answer, 6P=S. In the following problem,

> Write an equation using the variables C and S to represent the following statement: "At Mindy's restaurant, for every four people who ordered cheesecake, there were five who ordered strudel." Let C represent the number of cheesecakes ordered and S the number of strudels ordered,

where the problem statement is slightly more complicated than in the "students and professors" problem, the error rate for Anglo engineering majors rose to 61% out of 497 freshmen tested. Again, the majority of wrong answers consisted of students writing the variable-reversed equation, 4C=5S.

Clement et al. were able to show that few, if any of the errors stemmed from a misreading of the problem. In clinical interviews with over 20 students, none indicated that they believed there were more professors than students in the "students and professors" problem. The error appeared to stem

from misconceptions concerning the structure and interpretation of algebraic statements, and from the process by which one translates from natural language to symbolic language. Students who commit the variable-reversal error may have learned to perform algebraic manipulations, but they have not grasped how to conceptualize within the language of mathematics.

The actual mechanism used by most students who committed the variable-reversal error consists of using a sequential left-to-right translation of the problem statement. Hence, the phrase "six times as many students" becomes 6S, and by equating this to P, students believe that they have set up the appropriate relationship. From looking at the equation 6S=P, it is clear why it is very tempting to misinterpret its meaning as "six times as many students as professors," rather than its correct mathematical meaning: Multiplying the number of students, S, times 6 will give the number of professors, P--an obvious contradiction from what is stated in the problem. In other words, students are using the variables S and P, which are supposed to represent the number of students and professors, as labels for "students" and "professors."

In the 14-question FTE which we administered to a group of [illegible] Hispanic engineering students, we found results similar to those obtained by Clement, et al. However, the Hispanics committed the variable-reversal error with almost twice the frequency in comparison with a group of 52 Anglo engineers tested. More importantly, the Hispanic group exibited certain types of errors which were not committed by the Anglo group. Table 3, taken from Mestre, Gerace and Lochhead (1982), details the performance of these two groups of students on the FTE, and its Spanish counterpart, the TDF. The three entries on Table 3 correspond to Hispanics on the TDF, Hispanics on the FTE, and Anglos on the FTE, respectively. Each entry denotes the total number of students from that group in the respective categories shown, and is followed

in parentheses by the percentage that this number constitutes of the total number of students in the group. The row labeled "chi^2" is the result of a 2 by 2 chi-square analysis between the Hispanic group and the Anglo group on the FTE, taking into account the number correct versus the total number wrong in all categories. The significance level of the chi-squares is given as "p" on Table 3.

.....Insert Table 3 about here.....

To investigate the non-variable-reversal errors in more detail, we interviewed 9 Hispanics and 11 Anglos, all randomly selected from the two groups. These students were asked to "think aloud" while solving problem 1 of the FTE, namely, the "students and professors" problem, as well as problems 5 and 6 shown below.

FTE #5. Write an equation using the variables C and P to represent the following statement: "At a certain restaurant, for every four people who ordered cheesecake, there were five who ordered pie." Let C represent the number of cheesecakes ordered and P the number of pies ordered.

FTE #6. Write an equation to represent the following statement: "A certain council has 9 more men than women on it." Use M for the number of men and W for the number of women.

There were 5 types of errors uncovered during the interview sessions which were different from the variable-reversal error. These errors were committed only by the Hispanics interviewed and are described below:

Error #1. In the "students and professors" problem, some students wrote

6S=6P. The students who made this error explained that the phrase "as many students as professors" implies that there is an equal number of each, that is S=P. The "six times" in front of the statement was interpreted to mean that each side of S=P should be multiplied by 6.

Error #2. Again in the "students and professors" problem, some students wrote the answer as 6S+P=T. They explained that this equation related the number of students, professors, and the total student-professor population, T, in the appropriate proportions. After prompting, these students realized that the problem was asking for a relationship between S and P, and subsequently wrote 6S=P.

Error #3 In the "cheesecakes and pies" problem, some students wrote the answer as 4C/5P. When asked if this was an equation relating the number of people who ordered cheesecakes to the number of people who ordered pie, these students replied that the above fraction set up a "relationship" to express the appropriate ratios of cheesecakes to pies. Not all students could be prompted to write an equation, variable-reversed or otherwise, the claim being that this problem asked for a proportion between two variables and not an equality.

Error #4. Some students wrote 4C 5P for the "cheesecakes and pies" problem. Those writing this claimed that the 4-to-5 ratio of cheesecakes to pies did not allow one to write an equation relating the two variables. As evidence, the students pointed out that if 4 people bought cheesecakes, then 5 bought pies; if 8 bought cheesecakes, then 10 bought pies, and that clearly the two quantities were not ever going to equal each other.

These students claimed that the inequality they wrote expressed the fact that there would always be fewer cheesecakes than pies served at the restaurant. Lochhead (1980) has found this phenomenon among college professors, and points out that perhaps this is due to the nature of algebraic equations--that is, implicit in algebra is the ability to relate quantities which in fact are not equal by constructing an equation using appropriate weighting factors.

Error #5. In the "committee" problem, some students wrote 9M=W. This was by far the most common error among the non-variable-reversal types, with five out of the nine Hispanics interviewed committing it. It stems from interpreting the phrase "9 more men than women" to mean "nine times more men than women,", and then via the variable-reversal error, the answer 9M=W follows. After prompting, three out of the five students realized that the question called for an additive, rather than a multiplicative relationship. The remaining two students retained the notion that "9 more men than women" implied a multiplicative relationship. This appears to be an example of "functional fixedness"--that is, all problems previous to this one asked for a multiplicative relationship between two variables, and thus multiplicative relationships become functionally fixed in the students' minds, thereby adversely affecting the performance on subsequent problems requiring additive relationships.

Other detailed findings of the students' performance on the three questions listed in the previous section from the Word Problem Inventory suggest that the difficulties experienced by many of the students are

linguistic and not mathematical in nature. In the "engineering conference" problem, for example, the overall error rates for the Hispanic and Anglo groups were 47% and 27%, respectively. The incorrect answer which suggests possible linguistic difficulties consisted of students writing 9(28)-7=245. Since we do not have interview data on how the students reasoned to obtain this erroneous answer, all we can do is deduce some interpretation which would make the answer follow logically. Two misinterpretations working in unison would result in 9(28)-7=245 as the appropriate answer to the problem. These misinterpretations are 1) the term "participants" was taken to mean "those present at the meeting rooms listening to presentations" as opposed to the intended meaning of "all those registered at the conference no matter where they happened to be at the time of the presentations," and 2) an assumption was made that the coffee drinkers came out of the nine meeting rooms.

In the "carpenter" problem from the WPI, the error rate for Hispanics and Anglos was similar, namely, 57% and 42%, respectively. One type of error was made almost exclusively by the Hispanic group and accounted for 35% of all errors. It consisted of interpreting the first sentence in the problem, "a carpenter bought an equal number of nails and screws for $5.70," to mean that an equal amount of money was spent by the carpenter on nails and screws out of the total $5.70 spent. This interpretation resulted in the carpenter purchasing 95 screws and 147.5 nails. In the equivalent Spanish problem about "lapices y plumas" (i.e. about "pencils and pens"), there was an error rate of 31% for the Hispanic group. Why the error rate in Spanish was almost half of what it was in English is not clear--it may be due to the fact that the Spanish version is somewhat easier to work out by trial and error (a procedure used by some students); or perhaps the students found the Spanish version easier to understand. In either case, the type of error equivalent to the misinterpretation in the English version, in this case consisting of

interpreting the question to mean that an equal amount of money was spent on pens and pencils out of the total $.84 spent, accounted for 47% of all errors.

It therefore appears from the evidence at hand that subtleties in language construction, jargon, etc. increases the likelihood of problems being misinterpreted by Hispanic bilinguals. These misinterpretations are not caused by an unfamiliarity with vocabulary, per se. What is clear is that these students often translate a problem into mathematical terminology incorrectly, yet the interpretation is totally consistent with their own understanding of what the problem is asking. The result is a solution which is algebraically correct, but which suffers from an inappropriate translation from natural language to mathematical language.

Performance as a Function of Verbosity

Although we have demonstrated instances where the performance of Hispanics on word problems is adversely affected by inappropriate interpretations of phrases in the problem statement, the search for particular phrases or constructions that are apt to cause semantic difficulties is a tedious process. One can never predict with assurance whether a phrase will be prone to misinterpretation by students until they, de facto, misinterpret the phrase.

In an attempt to measure the effect of language comprehension within a mathematical problem solving context, another pair of word problem exams were constructed. Both exams contained 10 questions and required only a knowledge of elementary algebra. In the Terse exam, the questions were asked using simple, terse language. In the Verbose exam, the questions were embellished with technical jargon. Every question in the Terse exam had a verbose counterpart in the Verbose exam--that is, the pair of questions were of exactly the same mathematical content. A sample pair of "equivalent" problems

from the Terse and Verbose exams are shown below:

Terse: In a wholesale hardware store, 45 high intensity light bulbs sell for $50. At a local hardware store, the same light bulb sells for $1.10 each. What is the difference in price between buying 45 light bulbs at the two stores?

Verbose: Albert Einstein, the renowned theoretical nuclear physicist, showed that energy and mass could be thought of as equivalent quantities. Thus particles that are bound together should have a different rest mass than the same particles taken separately. Suppose that a collection of 45 bound particles are determined to have a rest mass of 50 MeV. Careful measurements also show that each of the particles, when examined on its own, has a rest mass of 1.1 MeV. Calculate the difference in rest mass between the 45 bound particles and the 45 unbound particles.

As is evident, the problems were algebraically easy since the aim was not to measure mathematical prowess, but rather language interference effects. In the Verbose exam, students were required to make various associations among the variables of the problems--something which was not necessary in the Terse exam. Any observable difference in performance between the Terse and Verbose exams would be one aggregate measure of the effect of language comprehension on problem solving.

Both exams were given to 60 Hispanic science and engineering majors, and to a corresponding group of 73 Anglos. The results are shown on Table 4. As Table 4 indicates, there were also Spanish versions of the Terse and Verbose exams administered to the Hispanic group. The differences in performance between the Terse and Verbose scores were statistically significant in all three cases. It appears that the Hispanic group's performance on the Spanish versions was worse than their performance in the English versions; the difference-mean was also larger in Spanish than in English for the Hispanic group, indicating more interference in Spanish.

.....Insert Table 4 about here.....

We hasten to point out that reliability measures for these tests show that they are better instruments for the Hispanic group than for the Anglo group. The Cronbach alpha coefficients for the Terse exam for Anglos, and for Hispanics in English and in Spanish, are .34, .72, and .68, respectively; for the Verbose exam, the corresponding alpha coefficients are .34, .75, and .74. The low reliability coefficients for the Anglo group were caused by a disproportionate distribution of the variance among the test items. There was little variance among most items for this group, and most of the overall variance can be attributed to two items in the Terse exam and to three items in the Verbose exam. We therefore believe that the difference-mean between the Terse and Verbose exams for the Anglo group is not so much a measure of the direct effect of language comprehension upon performance, but rather a measure of the likelihood of making silly errors due to the indirect effect of language comprehension. That is, because of the larger processing load placed on short term memory caused by the increased amounts of language processing necessary in working out the Verbose test, there is a greater chance of a "slip" resulting in a silly error.

On the other hand, we interpret the high reliability on both the Spanish and English versions of the Terse and Verbose exams for Hispanics to mean something else. The high alpha coefficients on the Terse exams mean that the item variances were not disproportionately distributed among just a few items, but were somewhat uniformly distributed; these items were of "adequate" mathematical difficulty for the Hispanic group. The fact that the mathematical level of the Terse exam was not unchallenging for the Hispanic group, in combination with the large difference-means between the Terse and Verbose exams, indicate that the difference-means for this group are a measure of an effect apart from, and also in addition to, the likelihood of making a silly error. It is our contention that this additional effect is due to the

direct interference of language when solving the verbose problems. That is, the combined load placed on short term memory caused by both mathematical and linguistic demands in the verbose problems results in a larger gap between the performance in the terse and verbose problems for this group.

Effect of Double Negatives and Biasing on Logic Problems

Our discussions of how language interacts with problem solving have thus far been restricted to one content area--mathematics. Another content area where language comprehension plays an important role is logical reasoning. We do not believe that it would take much argument to convince the reader that ability to reason logically is a skill that can be usefully transfered to many problem solving settings; whether it is writing a polemic essay or devising a strategy for attacking an intricate mathematical problem, in order to succeed in the task, the arguments or strategies adduced must be governed by proper logic.

A brief review of some of the extant literature on syllogistic reasoning reveals that subjects often use logical rules which are not valid. For example, in categorical syllogisms (i.e. those that begin "all As...", "no As...", or "some As...") subjects appear to prefer a conclusion that has the same form as the premises. For example, subjects are more likely to accept as valid a syllogism such as

Some As are Bs

Some Bs are Cs

Some As are Cs

but not a syllogism such as

Some As are Bs

Some Bs are Cs

All As are Cs

This led Woodworth and Sells (1935) to propose the "atmosphere hypothesis" which states that terms such as "some", "all", "no", and "not" used in syllogisms create an atmosphere in which subjects are apt to accept as valid conclusions with the same terms.

Other research by Johnson-Laird and Steedman (1978) has revealed that subjects are more likely to accept an invalid conclusion linking A to C, if they can form a continuous thread linking A to B, and B to C. Thus, subjects are more likely to accept as valid the first syllogism above over the following syllogism:

Some Bs are As

Some Cs are Bs

Some As are Cs

Subjects have also been known to read more into a premise than is logically allowed (Henle, 1962; Chapman and Chapman, 1959). For example, "all As are Bs" is often interpreted to mean "A is the same as B", while "some As are Bs" is interpreted to mean "some As are Bs but not all As are Bs and further, not all Bs are As". Another logical pitfall for subjects concerns the issue of "pragmatic deduction." Pragmatic deduction is characterized by subjects trading sound logical approaches for pragmatic truisms that are in accord with the situation in the real world (Chapman and Chapman, 1959; Henle, 1962; Reder, 1976).

One recent study by Duran (1981) investigated the logical reasoning skills of Puerto Rican bilingual college students. Several logical reasoning instruments (some dealing with syllogisms) were administered to the students in both English and Spanish. Standardized measures were also administered to evaluate the students' language proficiency in both English and Spanish. The results of this study showed that performance on logical reasoning tests in each language can be significantly predicted by language proficiency measures

in the language of the tests. Duran also found that the performance pattern was similar across languages for English-Spanish pairs of equivalent tests.

Logical reasoning research on semantics indicates that negative sentences are harder to comprehend than affirmative sentences. Whether measured by reaction time (Just and Carpenter, 1971; Carpenter and Just 1975; Trabasso, Rollins, and Shaughnessey, 1971), or by ability to recall (Miller, 1962; Mehler, 1963; Clark and Card, 1969), or by ability to verify (Wason, 1959, 1961; Anderson and Reder, 1974), there is abundant evidence that negative sentences give subjects more difficulties. Further, increasing the number of negations appears to create successive decrements in comprehension (Sherman, 1976; Johnson-Laird, 1970; Legrenzi, 1970).

The role of double negatives in the Spanish language takes on particular significance. In Spanish, certain constructions containing double negatives retain the negative meaning--something which is not found in (grammatically correct) English. Thus, the grammatically correct translation of the statement "I do not want any money" into Spanish is "yo no quiero ningun dinero," which, when literally translated back into English, becomes "I do not want no money." A question that immediately comes to mind is whether Hispanics are more likly to misinterpret doubly-negated statements when solving problems because of this logical inequivalence between the two languages. If true, this would have adverse ramifications for Hispanic students, since the usage of double negatives in the English language is not infrequent.

In view of the research findings above, and of the inequivalence between the English and Spanish languages concerning the meaning of certain double negative constructions, a study of the logical reasoning skills with our Hispanic technical students appeared to hold promise in extracting valuable insights, both into the thought processes used by the students, and into the

possible existence of language interference effects. To probe some of these questions, we constructed two logic tests containing 9 questions each, one in English and the other in Spanish. These tests were pilot tested on 60 Hispanics and 74 Anglos. To facilitate further discussion, we have included these tests in the Appendix.

Several aspects of these exams should be noted. Let us first consider the English version. Questions 3 and 6 are structurally equivalent; however, question 3 is biased since the correct answer, "all college graduates earn less the $10,000 a year," is counter-intuitive to the situation that exists in the "real world." Question 6, on the other hand, is not biased since students are not likely to have strong preconceptions concerning the yearly growth of fig trees. Similarly, questions 5 and 8 are also equivalent in structure; question 5 is the more biased question of the two, since most basketball players are, in fact, taller than 6 feet and the correct answer is "all basketball players are less than 6 feet tall;" question 8 is not so biased since most people realize that the number of seeds in oranges varies. These four questions were designed to assess the students' proclivity to resort to "pragmatic deduction"--if students show a significantly stronger performance on the unbiased questions, then we can interpret this as strong evidence that they are being deceived by their own preconceptions in the biased questions.

Other aspects to note are that there were at most two negations in any problem. Two problems, numbers 4 and 7, asked the students to interpret a pictorial diagram. Finally, in question 9, students were asked to determine whether the statement, "I do not want no money" meant that money was, or was not, wanted. Although it could be argued that the aforementioned quoted statement is of questionable grammatical construction, it does carry the same meaning as "I do not want money," albeit in a less forceful fashion. This problem should clearly illustrate whether Hispanics are likely to interpret

statements containing double negations differently than Anglos.

The Spanish version of the exam was not structurally equivalent to the English version, although the corresponding questions between the two tests were very similar. Therefore, before definitive comparisons can be made between the Hispanic group's performance across English and Spanish, more care should be taken to design two tests which are not only completely structurally equivalent, but also equivalent in the number, and difficulty of the vocabulary words used in corresponding English-Spanish questions. That is not to say that we cannot glean useful insights from the students' performance in the Spanish version which will aid in the design of subsequent instruments.

The means, standard deviations, and reliability coefficients for the logic tests are shown on Table 5. The Cronbach alpha was computed using only questions 1 through 8 of the tests. Also shown on Table 5 is a breakdown of the English version of the logic exams by question, showing the percentage of each group reponding correctly. The entries in the column labeled with chi^2 is the result of a 2 x 2 chi-square analysis between the Hispanics and the Anglos, taking into account the number correct versus the number wrong for each question.

.....Insert Table 5 about here.....

It appears from Table 5 that significant differences between the Anglo and Hispanic groups occur for questions 1, 4, 7, 8, and 9, and the differences in questions 5 and 6 approach significance. Considering only questions 1, 4, 7, and 8 for the moment, we found it surprising that only one of these,

question 8, contained two negations. Questions 1, 4, and 7 contained only one negation. On the surface, these results appear to indicate that there are no observable differences in the way Anglos and Hispanics interpret double negations. We find an alternate explanation more credible. It is evident from Table 5 that on the other three questions containing two negations, namely questions 3, 5, and 6 (again disregarding question 9 for the moment), both Hispanics and Anglos alike performed extremely poorly--in fact, the performance on biased questions 3 and 5 for both Hispanics and Anglos was at, or below, the level one would expect by randomly guessing the answer. It appears that questions 3, 5, 6, and 8 were too difficult to be able to observe differences in performance between the two groups due to double negations.

Returning to question 9, the significant differences in performance between the Anglo and Hispanic groups may be due to the logical inequivalence in the meaning of double negations between English and Spanish. In this question, the percentage of the Hispanic students who interpreted the double negation as an overall negation was 40%, compared to only 8% for the non-minority group. The results in this question illustrate that Hispanics may interpret double negations in English as they would have in Spanish. Another possible explanation is that Hispanics are using slang interpretaions of double negations more often than Anglos.

Although questions 3, 5, 6, and 8 proved to be extremely difficult for all the students, there is strong evidence that Hispanics and Anglos alike resorted to "pragmatic deduction" on biased questions 3 and 5. Table 6 shows the effect of belief-bias in the English version of the logic exam in more detail. As is evident from Table 6, the differences in performance between the biased questions, and the unbiased questions were statistically significant in the obvious direction for both groups.

.....Insert Table 6 about here.....

There is also evidence in support of the "atmosphere hypothesis." In Table 7, a detailed breakdown of the students' responses to questions 3, 5, 6, and 8 is given. This time we have also included the Hispanic group's performance in the Spanish problems. Taking into consideration only the three incorrect choices for these four questions, we can see that all students prefer the answer with "some..." by a wide margin. The chi-square statistic in Table 7 is a test among the three wrong answers for each question; we assumed the null hypothesis to mean that all three wrong answers were equally likely to be selected with probability 1/3. As we can see, the resulting chi-squares favor the rejection of the null hypothesis in favor of the atmosphere hypothesis. It is interesting to note that even among the unbiased questions where many more students from both groups selected the correct answer, the preferred wrong answer was the choice with the quantifier "some." Since the premise in questions 3 and 6 did not contain the quatifier "some," but rather "not all," it is also clear that to most students the phrase "not all" is equivalent to "some." A discussion to follow of how students solve these types of problems during clinical interviews using the "think aloud" method will also show that statements of the form "not all As are less than B" are interpreted by many students to mean "some As are less than B and some As are more than B."

.....Insert Table 7 about here.....

In order to investigate the cognitive processes employed by the students in solving these types of logic problems, we conducted clinical interviews with a total of 17 students, 8 from the Hispanic group, and 9 from the Anglo group. These interviews revealed that students preferred to employ "rules" in a mechanical fashion to solve these problems, rather than attempting to rephrase and understand the meaning of each problem in order to select the most suitable answer. Only one procedure employed by students consistently yielded the correct answer. This procedure can be summarized as follows:

> Break the sentence into components. Next analyze each part, starting with the innermost, and take into account each negation in turn until the statement of the problem is paraphrased into the correct answer.

This procedure is best illustrated with examples. In problems 3 and 5, it would work as follows:

Prob 3 Not all college graduates earn less than $10,000 per year means there must be some that earn more than, or equal to $10,000 per year. But if this is false, then all college graduates must earn less than $10,000 per year

Prob 5 Some basketball players are not less than 6 feet tall implies that some basketball players are more than, or equal to 6 feet tall. But if this is not true, then all must be less than 6 feet tall.

Only two of the students interviewed, both from the Anglo group, consistently applied this procedure successfully.

Far more frequently used than the above procedure were rules which were efficacious in obtaining the correct answer in some of the problems, but which resulted in specious logic when applied blindly to all problems. Five rules were clearly identified which students used singly, or in "packages" of two or more at a time. These rules are described below, along with verbatim quotes from the students' protocols illustrating their usage:

Rule 1 The phrase "not all" can be replaced with the word "some."

"We're saying 'not all college graduates,' so we're saying some."

"When you see the word 'not all' substitute 'some'."
"You have to sort of be logical. But I guess you can always put in 'some' for 'not all'."

Rule 2 Questions beginning with 'not all' or 'some' must have answers beginning with 'some'." This is direct evidence in support of the "atmosphere hypothesis."

"The key to this question is the 'not all,' that's how you know 'some' should be in the answer."
"Without looking at the answers, I know that the answer will have 'some' in it because the question says 'some'."

Rule 3 In questions where the world is dichotomized into two complementary and exhaustive categories (e.g. those earning less than $10,000, and those earning more than or equal to $10,000 per year), stating that some of the group is on one of the categories implies that there must be some in the complementary category. This phenomenon is in support of the findings of Henle (1962), and Chapman and Chapman (1959) who found that subjects read more into statements than is logically permitted.

"'not all' means some are going to be included and some aren't."
"I would go with 'some' because if not all earn less than $10,000, then some must earn less and some must earn more."

Rule 4 Negations can always be canceled in pairs.

"I cover up the first part of the question, and only cancel 'nots' within the statement that's being decided on."
"Two negatives make a positive so I pick 'a'."

Rule 5 If all else fails, resort to either intuition or experience in finding a suitable answer. This rule is in support of obtaining answers via "pragmatic deduction."

"I know people that like to eat steak and also like corn, but not all people that like to eat steak like to eat corn, just because I do."
"You can't say that 'all college graduates earn less than $10,000' because that goes against statistics. You can't pick 'c', even though that's what the answer seems like. I eliminate the answers that are very general, like 'd', because it's not true that all college graduates earn more than $10,000 in the real world. So I picked 'a'."

It should be pointed out that neither group differed appreciably in which of the five rules were used and in how they were applied. Although each group used these rules with approximately the same frequency, the percentage of correct responses exhibited during the interviews reflected the percentage of correct answers for each group as a whole, as shown in Table 5.

We are in the process of analyzing data from newly developed logic questions. These new questions are designed to a) explore in more detail the effect of biasing, b) explore in more detail the effect of adding extra negations, c) look at possible differences across language, and d) separate the difficulties due to understanding double negations from the difficulties deriving from other effects.

Preliminary analyses demonstrates the effect of adding extra negations upon performance. Let us consider the following two pairs of English and Spanish logic problems:

If it is not true that "all people who like to eat steak also like to eat corn," then we can conclude that:
a) All people who do not like to eat corn also do not like to eat steak.
b) Some people who like to eat steak do not like to eat corn.
c) All people who like to eat steak do not like to eat corn.
d) All people who like to eat corn also like to eat steak.
e) Some people who like to eat steak also like to eat corn.

If it is not true that "all yellow things are not made of gold," then we can conclude that:
a) Some yellow things are not made of gold.
b) All things not made of gold are yellow things.
c) All things not made of gold are not yellow.
d) Some yellow things are made of gold.
e) All yellow things are made of gold.

Si no es verdad que "todas las personas que les gusta zambullirse tambien les gusta nadar," entonces podemos concluir que:
a) Todas las personas que no les gusta nadar tampoco les gusta zambullirse.
b) Algunas personas que les gusta zambullirse no les gusta nadar.
c) Todas las personas que les gusta zambullirse no les gusta nadar.
d) Todas las personas que les gusta nadar tambien les gusta zambullirse.
e) Algunas personas que les gusta zambullirse tambien les gusta nadar.

Si no es verdad que "todos los objetos sólidos no son hechos de acero," entonces podemos concluir que:
a) Algunos objetos sólidos no son hechos de acero.
b) Todos los objetos no hechos de acero son sólidos.
c) Todos los objetos no hechos de acero no son sólidos.
d) Algunos objetos sólidos son hechos de acero.
e) Todos los objetos sólidos son hechos de acero.

It is clear that the structure differs between the two problems of each pair in that one of the problems contains one negation whereas the other contains two negations. The results on these problems as shown on Table 8 reveal that

the problems with the two negations are much harder to comprehend than the problems with only one negation. It appears that the Anglo group is most affected by the extra negation.

.....Insert Table 8 about here.....

Effect of Problem Solving Speed Upon Performance

One often neglected skill related to successful problem solving which has not been mentioned is problem solving speed. The reason why in our roles as instructors we often neglect to address speed is that we are much more interested in students being able to solve problems correctly, and not so much that they be able to do so in record speed. However, a complaint voiced by many of the Hispanics in our studies is that they often do not have adequate time to finish all of the problems given in the 50 minutes of the typical "hour exam," especially when they spent considerable time attempting to understand what is being asked.

We would like to illustrate the effect of speed in mathematical problem solving. Before doing so, we will start by quantifying how the Hispanics and Anglos in our studies differed in reading comprehension speed. In the Speed of Comprehension section of the TOR, students are required to read a sentence from which a word has been deleted and then select from among five choices that word which best fits in the space of the omitted word. The section is designed to measure the speed and accuracy with which a student can read and understand a sentence. The disparity in performance between the Hispanic and Anglo groups in this section as shown on Table 1 is largely due to the ability of the Anglo group to answer significantly more questions. In the six minutes

allowed for this section, the average number of questions attempted per student was 20.5 for the Anglo group compared to 15.3 for the Hispanic group.

The effect of problem solving speed in the WPI is shown in Figure 1. The bar graph area is representative of the total number of questions for the exam. From the "questions not reached" category, it is clear that time restrictions were responsible for the typical Anglo student not reaching 26% of the questions in this exam, and for the typical Hispanic student not reaching 49.6% of the questions. Thus the significantly better performance of the Anglo group in a test such as the WPI, which requires substantial amounts of linguistic processing, is largely due to the fact that they get to answer more of the problems in the allotted time.

.....Insert Figure 1 about here.....

Academic, Socioeconomic, and Motivational Factors

Thus far, no mention has been made of non-academic factors which have been shown to influence the achievement and aspiration levels of students. For example, it has been known for some time that socioeconomic status (SES) is positively correlated with academic achievement for non-minority students (Sewell, 1971; Sewell and Hauser, 1975). Similar studies which have shown significant positive correlations between SES and academic achievement for minority students are too numerous to reference. Since minority groups dominate the low income brackets, low academic achievement has often been attributed to ethnic group membership. However, the results from some recent studies indicate that ethnic group membership, per se, is not as important as measures of socioeconomic class membership in determining the educational

aspirations and achievement levels of minority students.

For example, in a study with college-bound Mexican-American females, Buriel and Saenz (1980) found that, in contrast to noncollege-bound Chicanas, college-bound Chicanas came from higher income families and were found to be more masculine and bicultural. Another study with Mexican-American high school students by Bender and Ruiz (1974) showed that class membership was more significant than race in determining levels of achievement and aspirations. In yet another study with Puerto Rican, Black, and Anglo adolescents, Dillard and Perrin (1980) found that after controlling for ethnic group membership and sex, factors associated with socioeconomic background are very influential in measures of career aspirations, career expectations, and maturity.

In view of the confounding effects that factors such as SES can have on academic achievement, we conducted an evaluation of several academic, socioeconomic, and motivational background characteristics of our Hispanic science and engineering students. To do this, we designed a questionnaire that probed three distinct areas related to the students' background. These areas were:

Academic Preparation: This section of the questionnaire consisted of eight questions aimed at clarifying the students' high school preparation in science and mathematics.

Motivational Factors: The six questions in this section were designed to isolate factors that had been influential in motivating the student to pursue a technical career. Some of the factors included were high school counseling, role models, and parental influence.

Socioeconomic Factors: This section consisted of six questions pertaining

to areas such as family income, the number and types of "technical toys" the student owned while growing up, and student employment experience.

The questionnaire format was in both open-coded and checklist style. Whenever possible, student responses were placed into two mutually exclusive categories (e.g. family income levels less than $20,000 per year, and more than $20,000 per year). When a question did not lend itself to two mutually exclusive categories, we devised the fewest number of categories necessary to exhaust all types of responses made by the students. The questionnaire was administered to 49 Hispanics and 53 Anglos--all of whom had participated in the studies we have discussed above. The statistical analysis consisted of cross-tabulating the answers by group, and evaluating the resulting chi-squares for significance at or beyond the .05 level. More details on this study can be found in Mestre and Robinson (1983).

Most of the similarities between the groups appeared in the Academic Preparation and Motivational Factors sections of the questionnaire. For example, responses to the questions under Academic preparation revealed that there were no significant differences between the two groups in high school grade point average. Under Motivational Factors, approximately the same number from each group indicated that they had decided to enter a technical field between the ages of 14-18, and that they knew friends or relatives employed in technical fields. The number of students in each group who claimed to have discussed career choices with their parents was also comparable. Only two similarities emerged in Socioeconomic Factors between the two groups--the majority of the students from both groups indicated that their mothers held no occupation outside the home. Similarly, those mothers from both groups who held employment outside the home held non-technical jobs.

The statistically significant differences between the two groups are

shown in Table 9. Most differences emerged under the Socieconomic Factors category. In areas such as family income, number of technical toys owned while growing up, and part-time employment prior to entering college, the Anglo group had a decided advantage. In view of the dismal representation of Hispanics in professional technical fields to which we alluded earlier, it is not surprising that many more of the Anglo fathers held occupations in technical fields in comparison to the Hispanic fathers.

.....Insert Table 9 about here.....

One other comparison was performed. The Hispanic group was divided into a high income group (those from families with incomes greater than $20,000 per year), and a low income group (those from families with incomes less than $20,000 per year). Comparisons were then made, using simple T-tests, between the performance of these two Hispanic subgroups on the Short Algebra Inventory, Word Problem Inventory, Formula Translation Examination, Test of General Ability-Computation, and the Test of Reading. The two subgroups' college performance, as measured by grade point average, was also compared. T-tests resulted in statistically significant differences in the obvious direction between low- and high-income Hispanics in the Word Problem Inventory, the Formula Translation Examination, Test of Reading-Vocabulary, and grade point average. There were not enough low-income Anglos in our sample to conduct a similar comparison for this group.

As in numerous other studies, our findings suggest that socioeconomic factors are influential in the academic achievement of the Hispanic college technical students that participated in our studies. It is interesting to

note that the only statistically significant difference between the Hispanic and Anglo groups under Academic Preparation was in the number of science courses taken while in high school; the Hispanic group averaged 3.61 science courses, while the Anglo group averaged 4.06 science courses. This difference in itself cannot be responsible for the mathematical underpreparedness exhibited by the Hispanic group, except perhaps indirectly, through SES or other variables. That is, the fact that many of the Hispanics in our sample came from low income brackets means that there is a higher likelihood that the education received by these students in their community schools was not on a par with the education received by the middle-class Anglo students. Thus, equivalent high school grade point averages or equivalent course loads might not imply equivalent academic preparation.

Summary and Discussion

Before summarizing the findings of the studies reviewed and discussing their implications, we would like to discuss some limitations with the work reviewed. Needless to say, the factors contributing to the "situation" as has been described in the studies above are complex and involve a combination of cultural, economic, linguistic, environmental, and educational factors. Although our studies have identified some central issues in the education and background characteristics of Hispanic college students, there is a danger that the findings may be interpreted as encompassing a wider spectrum than is warranted. We therefore caution the reader to take careful note of the following points:

1. Because our samples are small, we can never make any statements that would be as widely applicable as statements deriving from studies conducted with large national samples. However, the kinds of questions that can be studied with large samples are much different than the detailed questions one can investigate with small samples. Although

large sample studies are excellent in providing gross features, small sample studies can provide details which are useful in thinking about pedagogical questions.

2. Since there have been so few studies focusing on issues covering Hispanic college students, and even fewer focusing on Hispanic college technical students, there is a need for more research that will help replicate our findings, as well as provide us with new information which will aid in forming a well rounded picture of the current situation.

3. Finally, we would like to point out that there is no such thing as the "typical Hispanic." The educational issues relevant for first generation Mexican immigrants are much different from those that are relevant for the Chicanos of the west and southwest, or for the Cubans that emigrated 20 years ago, or for the Puerto Ricans living in New York City. Although the difficulties being faced by the Hispanics that participated in our studies are very probably similar to those being faced by other Hispanic technical college students in other parts of the country, there is no reason to expect a perfect overlap.

In summary, our findings indicate that the Hispanic technical college students that participated in our studies are underprepared in comparison to Anglo technical college students. The areas in which Hispanics displayed underpreparation are algebraic skills, language skills, and problem solving skills requiring substantial amounts of linguistic processing. We also found large differences in SES between the Hispanics and the Anglos of our studies. Finally, our findings indicate that various errors committed by the Hispanics in solving mathematics and logic problems are the result of semantic difficulties and not necessarily the result of difficulties in the content area.

To appreciate the role of language in the problem solving process more fully, it would help to consider the five steps one goes through in solving a mathematics problem:

1. Understanding the problem.
2. Developing a strategy of attack.
3. Translating the problem into the appropriate mathematical terminology.
4. Solving the mathematically translated problem.
5. Checking the answer.

With slight variation, these are the 5 steps that most would agree take place during problem solving. The steps in which language plays a crucial role are numbers 1 and 3. It is in these two steps that misinterpretations will result in errors before the problem is actually solved. It is our opinion that technical students with language deficiencies, such as the Hispanics of our studies, would benefit from problem solving courses which stress these two steps. Work in these two areas will not only help the students develop skills which are transferable to almost any problem solving domain, but will also allow the instructor to identify and address errors deriving from semantic difficulties.

The notion that language may have an effect on cognitive processes (not just for bilingual populations) is not new. For example, according to Vygotsky (1962), many facets of intellectual functioning are intimately related to language acquisition. Vygotsky also claims that the internalization of language induces a restructuring of many mental processes. In relation to problem solving, he states that problem solving strategies become more rational and sophisticated when they can be verbalized.

Another view, that of Whorf (1956), states that the language we speak can set certain limits or constraints on our perception. Perhaps the justification for this view derives more from cultural effects than from linguistic effects; that is, it may well be that cultural experiences are as important as linguistic experiences in forming our perceptions. The difficulty in the Whorfian hypothesis lies in how to distinguish between these two effects.

What is clear is that many Hispanic students are enrolling in technical college programs with language deficiencies which place them at a disadvantage when compared with their Anglo peers. Perhaps some of these linguistic

problems are inadvertently originated at the primary and secondary levels of schooling. Many transitional bilingual programs are allowed 3 years to prepare students of limited English proficiency to a level where they can be mainstreamed. At the end of 3 years, these programs turn out students who, although linguistically competent to function in the mainstream curriculum, are not linguistically proficient at a level where they can favorably compete academically with Anglo students.

A more lamentable situation is that there is no natural mechanism by which these students can improve their language proficiency level. For example, Anglo children can have their English language skills reinforced in the home, whereas Hispanic students who speak Spanish at home do not get similar reinforcement. Anglo children may enjoy reading books and magazines, whereas Hispanic children may not be abe to maintain interest in reading books and magazines if they either do not understand the nuances of the English language, or if their reading speed is slow enough to be bored by the pace at which they can process the "action" in what they are trying to read.

It appears to us that there is a decided need for more research in evaluating supplemental instructional approaches for improving the verbal and/or quantitative deficiencies of limited English proficiency students. We say supplemental since this would not require drastic modifications in the traditional instructional formats used in schools. For example, it is conceivable that microcomputers could be extremely effective if used in supplemental instructional programs which attempt to improve the vocabulary, reading speed, reading comprehension, mathematical, and problem solving skills of these students. Students with language or mathematical deficiencies could be asked to spend their "study periods" working with microcomputers on modules covering language skills or mathematical skills. Given that students seem to enjoy spending lots of time working on microcomputers, coupled with the

affordability of microcomputers for school systems, indicate that this approach has the potential to offer substantial educational relief for students with deficiencies, without being a threat to teachers.

References

Anderson, J. and Reder, L., Negative judgments in and about semantic memory, Journal of Verbal Learning and Verbal Behavior, 1974, 13, 664-681.

Bender, P.S. and Ruiz, R.A. Race and class as differential determinants of underachievement and underaspiration among Mexican-Americans and Anglos. Journal of Educational Research, 1974, 68, 51-55.

Board says minority-group scores helped push up averages on SAT. Chronicle of Higher Education, Oct. 20, 1982, p. 1; 10.

Brown, G.H., Rosen, N.L., Hill, S.T., and Olivas, M.A. National Center for Education Statistics. The Condition of Education for Hispanic Americans. U.S. Department of Education/NCES, Washington, D.C. 1980.

Buriel, R. and Saenz, E. Psychocultural characteristics of college-bound and noncollege bound Chicanas. Journal of Social Psychology, 1980,110, 245-251.

Carpenter, P.A. and Just, M. A. Sentence comprehension: a psycholonguistic processing model of verification. Psychological Review, 1975, 82, 45-73.

Chapman, L.J. and Chapman, J.P. Atmosphere effect reexamined. Journal of Experimental Psychology, 1959, 58, 220-226.

Clark, H.H. and Card, S.K. The role of semantics in remembering comparative sentences. Journal of Experimental Psychology, 1969, 82, 545-553.

Clement, J., Lochhead, J., and Monk, G.S. Translation difficulties in learning mathematics. American Mathematical Monthly, 1981, 88, 286-290.

Cummins, J. Linguistic interdependence and the educational development of bilingual children. Review of Educational Research, 1979, 49, 222-251.

DeAvila, E.A. and Duncan, S.F. "The language minority child: A psychological, linguistic, and social analysis", in J.E. Alatis (Ed.), Georgetown University Round Table on Languages and Linguistics 1980: Current Issues in Bilingual Education. Washington, D.C.: Georgetown University Press, 1981.

Dillard, J.M. and Perrin, D.W., Puerto Rican, Black, and Anglo adolescents' career aspirations, expectations, and maturity. Vocational Guidance Quarterly,1980, 28, 313-321.

Duran, R.P. Reading comprehension and the verbal deductive reasoning of bilinguals in R.P. Duran (Ed.) Latino Language and Communicative Behavior.Norwood, N.J.: Ablex, 1981.

Educational Testing Service. College Board Scholastic Aptitude Test. Princeton, N.J.: Author, 1942-1983.

Facundo, Blanca. The foundation response: Results of the Latino Institute Study. Hispanics and Grantmakers, Council on Foundations, Inc., Washington, D.C. 1981, p. 31-33.

Gerace, W.J. and Mestre, J.P. "A study of the cognitive development of Hispanic adolescents learning algebra using clinical interview techniques". Final Report National Institute of Education contract #400-81-0027. Department of Physics & Astronomy, University of Massachusetts, Amherst, 1982.

Guidance Testing Associates. Test of General Ability, Level 5, Advanced Form CE. San Antonio, Texas, 1962.

Guidance Testing Associates. Test of Reading, Level 5. San Antonio, Texas, 1962.

Henle, M. On the relation between logic and thinking. Psychological Review, 1962, 69, 366-378.

Hopkins, K. and Glass, G. Basic Statistics for the Behavioral Sciences. Englewood Cliffs, N.J.: Prentice-Hall, 1978.

International Institute of Teachers College, Columbia University. "A survey of the public educational system of Puerto Rico". Bureau of Publications, Teachers College, Columbia University, New York. 1926.

Johnson-Laird, P.N. Linguistic complexity and insight into a deductive problem. In G.B. Flores d'Arcais & W.J.M. Levelt (Eds.) Advances in Psycholinguistics. Amsterdam: North Holland, 1970.

Johnson-Laird, P.N. and Steedman, M. The psychology os syllogisms. Cognitive Psychology. 1978, 10, 64-99.

Just, M.A. and Carpenter, P.A. Comprehension of negation with quantification. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 244-253.

Kellaghan, J. and Macnamara, J. "Reading in a second language in Ireland". In D. Jenkinson (Ed.), Reading Instruction: An International Forum - Proceedings of the 1st World Congress on Reading. Newark, DE: International Reading Association, 1968.

Kolers, P.A. Reading and talking bilingually. American Journal of Psychology, 1966, 79, 357-376.

Lambert, W.E., Havelka, J. and Gardner, R.C. Linguistic manifestations of bilingualism. American Journal of Psychology, 1959, 72, 77-82.

Legrenzi, P. Relations between language and reasoning about deductive rules. In G.B. Flores d'Arcais and J.J.M. Levelt (Eds.). Advances in Psycholinguistics. Amsterdam: North Holland, 1970.

Lochhead, J. Faculty interpretations of simple algebraic statements: The professor's side of the equation. Journal of Mathematical Behavior, 1980, 3, 29-37.

Macnamara, J. The effects of instruction in a weaker language. Journal of Social Issues, 1967, 23, 121-135.

Mehler, J. Some effects of grammatical transformations on the recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 346-351.

Mestre, J.P. Predicting academic achievement among bilingual Hispanic college technical students. Educational and Psychological Measurement, 1981, 41, 1255-1264.

Mestre, J.P., Gerace, W.J., and Lochhead, J. The interdependence of language and translational math shills among bilingual Hispanic engineering students. Journal of Research in Science Teaching, 1982, 19, 399-410.

Mestre, J.P. and Robinson, H. Academic, socioeconomic, and motivational characteristics of Hispanic college students enrolled in technical programs. Vocational Guidance Quarterly, 1983, 31, 187-194.

Miller, G.A. Some psychological studies of grammar. American Psychologist, 1962, 17, 748-762.

Ramirez, M. and Castañeda, A. Cultural democracy, bicognitive development, and education. New York: Academic Press, 1974.

Reder, L.M. The role of elaborations in the processing of prose. Unpublished doctoral dissertation, University of Michigan, 1976.

Sewell, W.H. nd Hauser, R.M. Education, Occupation, and Earnings: Achievement in the Early Career. New York: Academic Press, 1975.

Sewell, W.H. Inequality of opportunity for higher education. American Sociological Review, 1971, 36, 793-809.

Sherman, M. Adjectival negation and the comprehension of multiply-negated sentences. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 143-157.

Trabasso, T., Rollin, H., and Shaughnessey, E. Storage and verification shapes in processing concepts. Cognitive Psychology, 1971, 2, 231-289.

Vasquez, M.J.T. Confronting barriers to the participation of Mexican-American women in higher education. Hispanic Journal of Behavioral Sciences, 1982, 4, 147-165.

Vygotsky, L.S. Thought and Language. Cambridge, MA: MIT Press, 1962.

Wason, P.C. Response to affirmative and negative binary statements. British Journal of Psychology, 1961, 52, 133-142.

Wason, P.C. The processing of positive and negative information. Quantitative Journal of Experimental Psychology, 1959, 11, 92-107.

Whorf, B. Language, Thought and Reality. Cambridge, MA: Wiley, 1956.

Woodworth, R.S. and Sells, S.B. An atmospheric effect in formal syllogistic reasoning. Journal of Experimental Psychology, 1935, 18, 451-460.

APPENDIX

English and Spanish
Logic Exams

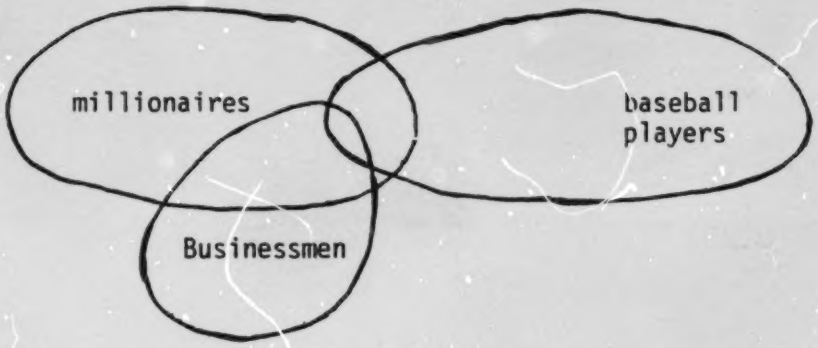
English Logic

1. If the statement "All people that like to eat steak also like to eat corn" is false, then this implies:
   a) All people that do not like to eat corn also do not like to eat steak.
   b) Some people that like to eat steak do not like to eat corn.
   c) All people that like to eat steak do not like to eat corn.
   d) All people that like to eat corn also like to eat steak.

2. If it is false that "All that is yellow is also gold," then we can conclude that:
   a) All that is gold is also yellow.
   b) All that is gold is also not yellow.
   c) Some yellow things are not gold.
   d) All that is yellow is not gold.

3. If it is false that not all college graduates earn less than $10,000 a year, then it must be true that:
   a) Some college graduates earn more than $10,000 a year.
   b) All college graduates do not earn less than $10,000 a year.
   c) All college graduates earn less than $10,000 a year.
   d) All college graduates earn more than $10,000 a year.

4. Which of the following statements is directly implied by the diagram below:

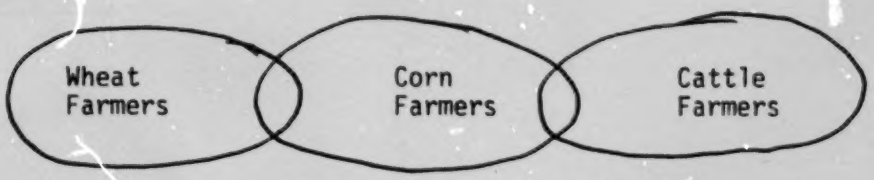


   a) All baseball players that are millionaires are also businessmen.
   b) All baseball players that are not millionaires are also not businessmen.
   c) There are not any millionaire baseball players who are also businessmen.
   d) There are no millionaires that are not baseball players.

5. If it is not true that some basketball players are not less than 6 feet tall, then this implies:
   a) All basketball players are not less than 6 feet tall.
   b) Some basketball players are more than 6 feet tall.
   c) All basketball players are more than 6 feet tall.
   d) All basketball players are less than 6 feet tall.

6. If it is false that not all fig trees grow more than 6 inches per year, then it must be true that:
   a) Some fig trees grow less than 6 inches per year.
   b) All fig trees do not grow more than 6 inches per year.
   c) All fig trees grow less than 6 inches per year.
   d) All fig trees grow more than 6 inches per year.

7. Which statement is implied by the following diagram:



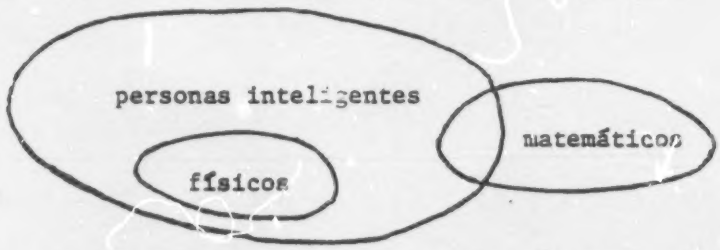
   a) There are no wheat farmers that are also corn and cattle farmers.
   b) Some wheat farmers are also cattle farmers.
   c) No corn farmers are also cattle farmers.
   d) All wheat farmers are also cattle farmers.

8. If it is not true that some oranges contain not less than 14 seeds, then this implies:
   a) Some oranges contain more than 14 seeds.
   b) All oranges contain not less than 14 seeds.
   c) All oranges contain less than 14 seeds.
   d) All oranges contain more than 14 seeds.

9. The statement "I do not want no money" implies:
   a) I want some money.
   b) I do not want some money.

6. Si es falso que no todos que toman vitamina C cogen menos que 3 catarros al año, entonces podemos concluir que:
   a) Algunos que toman vitamina C cogen más que 3 catarros al año.
   b) Todos que toman vitamina C no cogen menos que 3 catarros al año.
   c) Todos que toman vitamina C cogen menos que 3 catarros al año.
   d) Todos que toman vitamina C cogen más que 3 catarros al año.

7. ¿Cuál declaración de abajo implica este diagrama:



   a) Todas las personas inteligentes son físicos o matemáticos.
   b) Algunos matemáticos no son inteligentes.
   c) Todas las personas inteligentes son físicos.
   d) Algunos matemáticos también son físicos.

8. Si no es verdad que algunos estudiantes llevan no menos que $10 en su cartera, entonces quiere decir que:
   a) Todos los estudiantes no llevan menos que $10 en su cartera.
   b) Algunos estudiantes llevan más que $10 en su cartera.
   c) Todos los estudiantes llevan menos que $10 en su cartera.
   d) Todos los estudiantes llevan más que $10 en su cartera.

9. Si en una fiesta, no hay ninguno que no le gusta tomar cerveza, entonces quiere decir:
   a) A todos en la fiesta le gusta tomar cerveza.
   b) A ninguno en la fiests le gusta tomar cerveza.

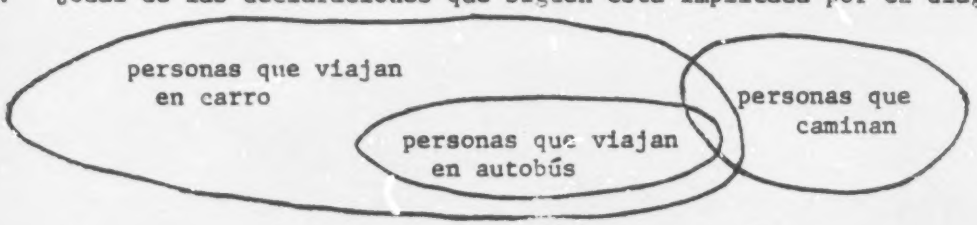
Spanish Logic

1. Si la declaración "Todos que le gusta ir a la playa también le gusta nadar" es falsa, entonces podemos decir:
   a) Todos que no le gusta nadar también no le gusta ir a la playa.
   b) Algunos que le gusta ir a la playa no le gusta nadar.
   c) Todos que le gusta ir a la playa no le gusta nadar.
   d) Todos que le gusta nadar también le gusta ir a la playa.

2. Si es falso que "Todos objetos lindos son objetos verdes", entonces se puede concluir que:
   a) Todos los objetos verdes son objetos lindos.
   b) Todos los objetos verdes no son objetos lindos.
   c) Algunos objetos lindos no son objetos verdes.
   d) Todos los objetos lindos no son objetos verdes.

3. Si es falso que no todos los estudiantes que sacan buenas notas en la escuela secundaria (high school), sacan malas notas cuando van a la universidad, entonces tiene que ser verdad que:
   a) Algunos estudiantes que sacan buenas notas en la escuela secundaria sacan buenas notas cuando van a la universidad.
   b) Todos los estudiantes que sacan buenas notas en la universidad también sacaron buenas notas en la escuela secundaria.
   c) Todos los estudiantes que sacan buenas notas en la escuela secundaria, sacan malas notas cuando van a la universidad.
   d) Todos los estudiantes que sacan buenas notas en la escuela secundaria, sacan buenas notas cuando van a la universidad.

4. ¿Cuál de las declaraciones que siguen está implicada por el diagrama:



   a) Hay personas que caminan y viajan en carro pero que no viajan en autobús.
   b) Todas las personas que viajan en autobús también caminan.
   c) No hay nadie que viaje en carro y también en autobús, pero que no camine.
   d) Algunas personas que viajan en autobús no viajan en carro.

5. Si es falso que no todos los que pueden leer con mucha rapidez leen menos que 2 libros al año, entonces podemos concluir que:
   a) Todos los que pueden leer con mucha rapidez leen menos que 2 libros al año.
   b) Algunos que pueden leer con mucha rapidez leen más que 2 libros al año.
   c) Todos los que pueden leer con mucha rapidez no leen menos que 2 libros al año.
   d) Todos que pueden leer con mucha rapidez leen más que 2 libros al año.

FIGURE 1

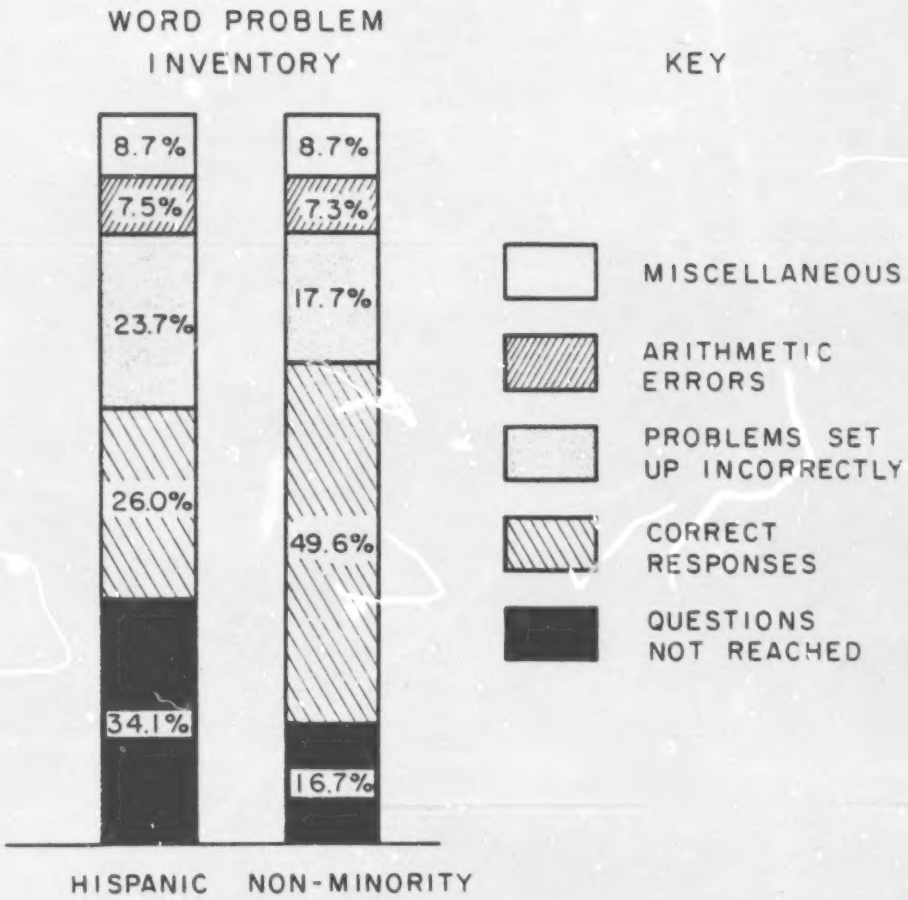

WORD PROBLEM
INVENTORY
KEY
8.7%
7.5%
23.7%
26.0%
34.1%
8.7%
7.3%
17.7%
49.6%
16.7%
MISCELLANEOUS
ARITHMETIC ERRORS
PROBLEMS SET UP INCORRECTLY
CORRECT RESPONSES
QUESTIONS NOT REACHED
HISPANIC
NON-MINORITY

Table 1

MEANS AND STANDARD DEVIATIONS

Exam	Max. Score	BILINGUALS N=60 Spanish Mean	Spanish Sta. Dev.	English Mean	English Sta. Dev.	MONOLINGUALS N=73 English Mean	English Sta. Dev.
Grade Point Average*	4.0	--	--	2.33	.77	2.62	.73
TOR-Vocabulary	45	29.0	9.0	29.8	7.5	36.0	4.0
TOR-Speed of Comprehension	30	11.5	4.8	10.9	4.5	18.0	4.3
TOR-Level of Comprehension	50	23.0	7.9	24.8	8.0	35.1	6.1
TOGA-Computation	26	10.4	4.8	10.4	4.8	14.5 (N=52)	5.5
Short Algebra Inventory	40	22.4	8.8	19.3	9.3	30.3	7.5
Word Problem Inventory	30	10.7	5.6	9.3	4.5	16.3	4.6
Formula Translation Examination	14	5.1	4.6	5.2	4.3	9.5	4.4
SAT Verbal	800	--	--	327 (N=26)	96	482 (N=62)	71
SAT Math	800	--	--	435 (N=26)	128	597 (N=62)	73

*The GPA of the total student population and the engineering student population are 2.63 and 2.59, respectively.

Pearson Correlation Coefficients Among Variables

	VARIABLES	1	2	3	4	5	6	7	8	9	10
1	GPA	1									
2	TOR-VOCABU-LARY	48*** 48*** 26*	1								
3	TOR-SPEED OF COMPREHEN-SION	23* 30* 14	70*** 60*** 46***	1							
4	TOR-LEVEL OF COMPREHEN-SION	40*** 36** 13	71*** 64*** 53***	71*** 74*** 47***	1						
5	TOGA- a COMPUTATION	40*** 40*** -04	25* 37** -01	18 48*** 18	37** 36** 06	1					
6	SHORT ALGEBRA INVENTORY	43*** 32** 31**	41*** 40*** 05	30** 46*** 13	45*** 33** 17	69*** 81*** 47***	1				
7	WORD PROBLEM INVENTORY	44*** 49*** 36***	37** 53*** 24*	29* 36** 27*	47*** 41*** 17	57*** 56*** 42***	54*** 63*** 60***	1			
8	FORMULA TRANSLATION EXAMINATION	32** 37** 38***	36** 44*** 27*	12 33** 16	29* 31** 12	45*** 46*** 17	48*** 46*** 27*	44*** 53*** 26*	1		
9	SAT VERBAL b	- 12 35**	- 52** 64***	- 64*** 59***	- 63*** 61***	- 55** 24	- 49** 23*	- 47** 27*	- 54** 26*	1	
10	SAT MATH b	- 42* 53***	- 55** 45***	- 54** 34**	- 51** 29*	- 74*** 45***	- 85*** 63***	- 87*** 65***	- 74*** 41***	- 59*** 48***	1

Note: The first, second, and third of the entries correspond to bilinguals taking Spanish version of tests, bilinguals participating in English version of tests, and monolinguals, respectively.
Decimal points have been omitted; *p<.05, **p<.01, ***p<.001 level
a) N=52 for monolinguals; b) N=62 for monolinguals and N=26 for bilinguals

Table 3 Performance on Formula Translation Exams

	Problem Number						
	1	2	3	4	5	6	7
Correct	18(41.9) 14(32.6) 35(67.3)	16(37.2) 19(44.2) 39(75.0)	16(37.2) 17(39.5) 33(63.5)	24(55.8) 22(51.2) 44(84.6)	8(18.6) 8(18.6) 23(44.2)	10(23.3) 17(39.5) 45(86.5)	10(23.3) 6(14.0) 33(63.5)
Variable reversal error	20(46.5) 23(53.5) 16(30.8)	23(53.5) 20(46.5) 13(25.0)	24(55.8) 19(44.2) 19(36.5)	11(25.6) 8(18.6) 4(7.7)	26(60.5) 28(65.1) 27(51.9)	7(16.3) 6(14.0) 4(7.7)	23(53.5) 24(55.8) 18(34.6)
Other error	5(11.6) 6(14.0) 1(1.9)	4(9.3) 4(9.3) 0(0)	3(7.0) 7(16.3) 0(0)	6(14.0) 11(25.6) 3(5.8)	7(16.3) 5(11.6) 2(3.9)	26(60.5) 19(44.2) 3(5.8)	9(20.9) 12(28.0) 1(1.9)
No answer	0(0) 0(0) 0(0)	0(0) 0(0) 0(0)	0(0) 0(0) 0(0)	2(4.7) 2(4.7) 1(1.9)	2(4.7) 2(4.7) 0(0)	0(0) 1(2.3) 0(0)	1(2.3) 1(2.3) 0(0)
χ^2	11.4	9.4	5.4	11.9	6.3	21.9	23.1
p	.001	.005	.025	.001	.025	.001	.001

	Problem Number						
	8	9	10	11	12	13	14
Correct	15(34.9) 19(44.2) 40(76.9)	14(32.6) 21(48.8) 38(73.1)	18(41.9) 19(44.2) 35(67.3)	31(72.1) 29(67.4) 44(84.6)	8(18.6) 5(11.6) 22(42.3)	10(23.3) 14(32.6) 37(71.2)	7(16.3) 8(18.6) 30(57.7)
Variable reversal error	23(53.5) 19(44.2) 11(21.2)	19(44.2) 17(39.5) 13(25.0)	20(46.5) 17(39.5) 17(32.7)	6(14.0) 5(11.6) 6(11.5)	26(60.5) 28(65.1) 28(53.9)	8(18.6) 5(11.6) 4(7.7)	25(58.1) 18(41.9) 19(36.5)
Other error	4(9.3) 5(11.6) 1(1.9)	8(18.6) 4(9.3) 1(1.9)	4(9.3) 4(9.3) 0(0)	4(9.3) 3(7.0) 1(1.9)	5(11.6) 3(7.0) 0(0)	21(48.8) 15(34.9) 10(19.2)	9(20.9) 5(11.6) 2(3.9)
No answer	1(2.3) 0(0) 0(0)	2(4.7) 1(2.3) 0(0)	1(2.3) 3(7.0) 0(0)	2(4.7) 6(14.0) 1(1.9)	4(9.3) 7(16.3) 2(3.9)	4(9.3) 9(21.0) 1(1.9)	2(4.7) 12(27.9) 1(1.9)
χ^2	10.7	5.3	3.7	.9	8.8	8.4	8.5
p	.005	.025	N.S.	N.S.	.005	.005	.005

Note: The three entries correspond to bilinguals in Spanish, bilinguals in English, and monolinguals in English, respectively. The number of students is followed in parentheses by the percentage this number constitutes of the total.

TABLE 4. Effect of Verbosity on Problem Solving Performance

	HISPANIC N=60				Anglo N=73	
	Spanish		English		English	
	Mean	Sta.Dev.	Mean	Sta.Dev	Mean	Sta.Dev.
TERSE	6.87	2.01	7.82	1.99	9.26	.94
VERBOSE	4.40	2.39	6.45	2.51	8.56	1.30
D=TERSE-VERBOSE	2.47*	1.72	1.37*	1.44	.70*	1.28

*$p < .01$

Table 5

Results of Logic Exams found in Appendix

	Hispanic N=60		Non-Minority N=74
	Spanish	English	English
Mean	3.85	4.10	5.59
Sta. Dev.	1.68	2.18	1.73
Cronbach	.47	.59	.54

Maximum score on each is 9

Percentage Correct: English Version Only

Question Number	Hispanic	Non-Minority	Chi^2
1	55.0	79.7	9.4*
2	60.0	60.8	0
3	13.3	17.6	.4
4	53.3	86.5	17.9*
5	13.3	27.0	3.8
6	33.3	48.6	3.2
7	78.3	91.9	5.0*
8	28.3	54.0	9.6*
9	60.0	91.9	19.4*

* Significant beyond the .05 level

Table 6

Effect of "Pragmatic Deduction" on Questions 3, 5, 6, and 8 of English Logic Exam

	Means and Standard Deviations			
	Biased Questions #3 & #5 Combined	Unbiased Questions #6 & #8 Combined	Difference-Mean (#6,#8)-(#3,#5)	t-Statistic Diff.-Mean
Hispanic (N=60)	.27 (.48)	.58 (.77)	.32 (.68)	3.6*
Anglo (N=74)	.46 (.69)	1.03 (.76)	.57 (.81)	6.0*

*$p < .001$

Table 7: Test of "Atmosphere Hypothesis" on Questions 3, 5, 6, and 8 of English and Spanish Logic Exams.

	Question Number			
	3	5	7	9
HISPANICS IN SPANISH				
Correct Response	(c)6	(a)7	(c)13	(c)9
Response with "some..."	(a)37	(b)31	(a)39	(b)37
Wrong "all..." Response	(b)5	(c)5	(b)5	(a)4
Wrong "all..." Response	(d)12	(d)15	(d)3	(d)10
Chi-sq on Wrong Answers (Degrees of Freedom = 2)	31.4*	20.2*	52.2*	36.4*
HISPANICS IN ENGLISH				
Correct Response	(c)8	(d)8	(d)20	(c)16
Response with "some..."	(a)35	(b)37	(a)29	(a)32
Wrong "all..." Response	(b)8	(a)5	(b)7	(b)8
Wrong "all..." Response	(d)9	(c)10	(c)4	(d)4
Chi-sq on Wrong Answers (Degrees of Freedom = 2)	27.0*	34.2*	28.0*	31.3*
ANGLOS IN ENGLISH				
Correct Response	(c)13	(d)20	(d)36	(c)40
Response with "some..."	(a)42	(b)33	(a)28	(a)26
Wrong "all..." Response	(b)9	(a)12	(b)5	(b)3
Wrong "all..." Response	(d)10	(c)9	(c)5	(d)5
Chi-sq on Wrong Answers (Degrees of Freedom = 2)	34.7*	19.0*	27.8*	28.6*

*$p < .001$

NOTE: The Chi-square test assumes a null hypothesis which has all wrong answers distributed equally among the three incorrect responses.

Table 8: Effect of Additional Negation

	Means and Standard Deviations			
	1 negation	2 negations	Difference-Mean	t-Statistic Diff.-Mean
Hispanics(N=49)				
Spanish	.65 (.48)	.31 (.47)	.35 (.56)	4.3*
English	.69 (.47)	.24 (.43)	.45 (.61)	5.12*
Anglos(N=53)				
English	.89 (.32)	.26 (.45)	.62 (.56)	8.1*

*$p < .001$

Table 9

Differences Between the Groups in the Three Categories Surveyed

Question Topic	Categories	χ^2	df	P	N Hispanic	N Anglo
	Academic Preparation					
Number of Science Courses Completed in High School	a) < 3 b) > 3	7.58	1	.05	49	53
	Motivational Factors					
Received Career Counseling in High School	a) Yes b) No	13.48	1	.0005	44	50
Reasons for Deciding to Pursue Technical Field	a) Encouragement and Interest b) Interest Only c) Other	15.01	2	.0005	48	52
	Socioeconomic Factors					
Father's Occupation	a) Technical b) Non-Technical	8.35	1	.01	41	49
Family Yearly Income	a) ≤$30,000 b) >$30,000	7.80	1	.01	41	49
Number of Technical Toys Owned	a) ≤5 b) >5	5.91	1	.05	45	50
Held Part-time Employment During High School	a) Yes b) No	9.08	1	.005	47	51

Appendix A

This Appendix contains an article entitled "Predicting Academic Achievement Among Bilingual Hispanic College Technical Students". This article was published in Educational and Psychological Measurement (1981, 41).

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Appendix B

This Appendix contains an article entitled "The Interdependence of Language and Translational Math Skills Among Bilingual Hispanic Engineering Students". This article was published in the Journal of Research in Science Teaching (vol. 19, no. 5, pp. 399-410, 1982).

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Appendix C

This Appendix contains an article entitled "Factors Influencing the Performance of Bilingual Hispanic Students in Math and Science Related Areas". This article was published in Integrated Education (vol. XVIII, nos. 5-6, December, 1981).

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Appendix D

This Appendix contains an article entitled "The Current Status of Hispanic Technical Professionals: How can we Improve Recruitment and Retention?" This article was published in Integrated Education (vol. 20, nos. 3-4, 1982).

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Appendix E

This Appendix contains and article entitled "Academic, Socioeconomic, and Motivational Characteristics of Hispanic College Students Enrolled in Technical Programs". This article was published in Vocational Guidance Quarterly (1983, 31, 187-194).

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Appendix F

This Appendix contains a book chapter entitled "The Latino Science and Engineering Student: Some Recent Research Findings". The chapter will appear in Latino College Students, (M. Olivas, Ed.), Teachers College Press, Columbia University, New York. Expected in late 1983.